Management of Wyoming Ponderosa Pine to Increase Profitability or Generate Carbon Credits

Why should forestland owners be interested in "Forest Carbon Credit?"

Increasing concentrations of carbon dioxide gas (CO_2) in our atmosphere is thought to lead to changes in global climate and has spawned national and international policies to slow down the rate of CO_2 emissions as well as management practices that increase carbon sequestration. Trees remove CO_2 from the atmosphere and store carbon in their biomass, with additional carbon sequestration in soil organic matter that is derived from biological processes involved in converting plant and microbial carbon compounds into soil carbon pools. There has been considerable interest in using economic incentives to reduce atmospheric concentration of CO_2 through the development of a carbon credit trading market. If changes in forest management practices can generate increased carbon levels at a cost competitive with credits from other sectors of the economy, this could present an opportunity to market Wyoming's forests while creating an additional income source for forest landowners.

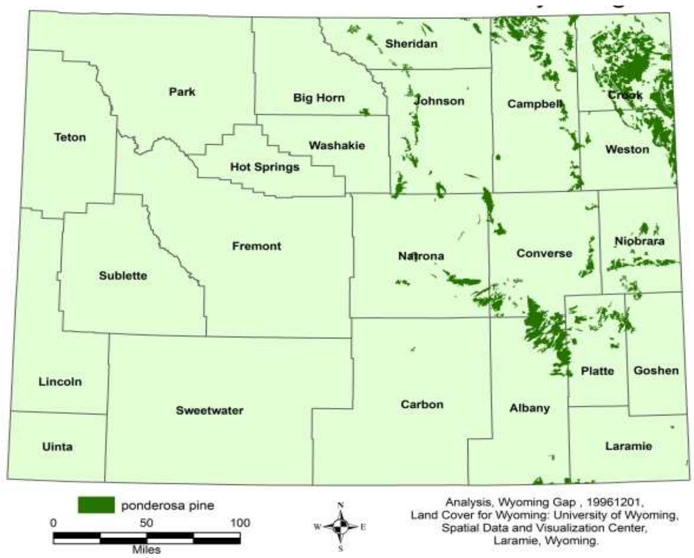

Figure *1. Distribution of ponderosa pine in Wyoming*

Ponderosa pine occurs almost exclusively in the eastern half of Wyoming (Figure 1). Of the marketable timber species in the state, ponderosa pine exhibits the highest private ownership with 905,000 acres of the total 1.4 million acres held privately ***(Green and Conner, 1989).*** It is therefore important to understand carbon storage of the ponderosa pine ecosystem under different forest management systems and to evaluate the economics of each of these systems when related to carbon storage.

Carbon storage in a forest ecosystem

Carbon storage in a forest ecosystem can be divided into three major pools (Figure 2):

(i) *Aboveground carbon pool*: consists of live (living trees, saplings, and herbaceous) and dead (standing dead trees, downed wood) biomass.

(ii) *Forest floor*: Fresh and partially decomposed litter layers that lie just above the soil mineral surface.

(iii) *Belowground carbon pool*: soil, root, and microbial biomass.

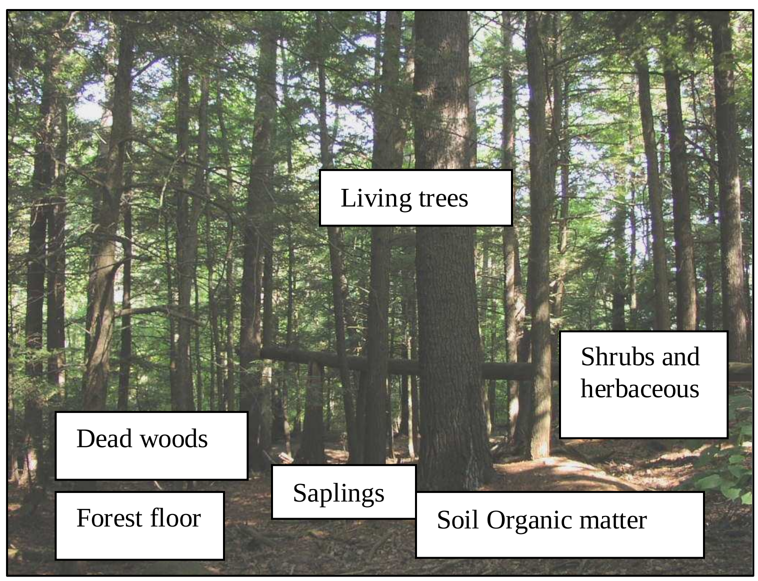

Figure 2. Forest carbon compartments

How does a forest store carbon?

The processes involved in carbon storage and release in a forest is depicted in Figure 3. In a forest ecosystem, plants assimilate atmospheric CO_2 and transform the carbon into sugars with the help of sunlight and water through the 'photosynthetic process.' Plants use this sugar as their energy source for growth and reproduction. Part of the assimilated CO_2 is incorporated into plant biomass (e.g., leaves, roots, and branches) and the rest of the CO_2 is released into the atmosphere through plant respiration. Dead tree biomass and leaves are added to the soil and are transformed into soil organic matter through the action of soil microorganisms. Soil microbes consume organic biomass for their energy and structural components, and then also respire CO_2. Thus atmospheric CO_2 is stored in plant biomass through the photosynthesis process and is also released to the atmosphere by plant and animal respiration. The resulting carbon constituents can be stored in plant biomass and soil organic matter.

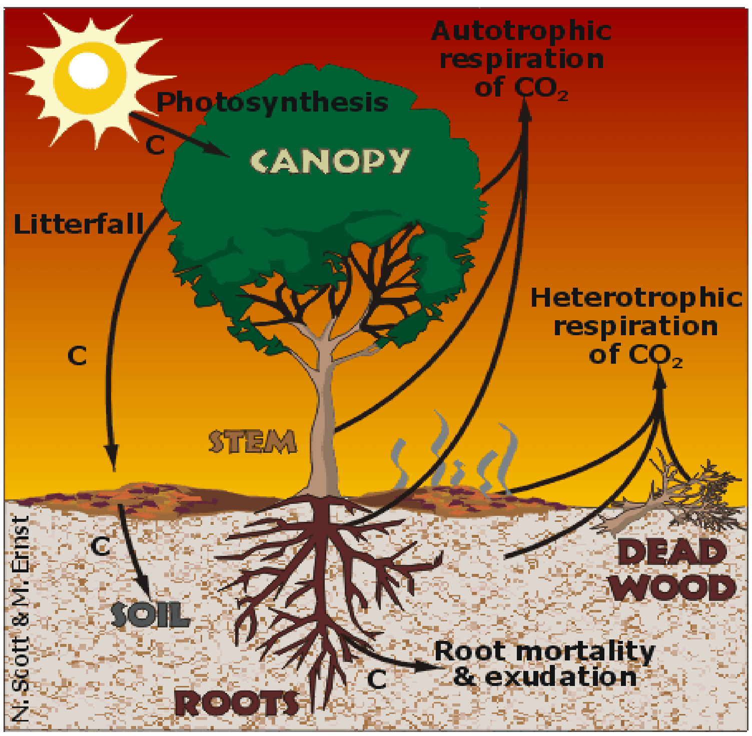

Figure 3. Forest carbon cycle *(Source: www.whrc.org)*

The magnitude of carbon storage in a forest ecosystem depends, at least in part, on how the forest is being managed. Carbon storage increases with increasing forest biomass over time. Old growth forests, which may have large stocks of C, often exhibit reduced annual carbon sequestration rates since net biomass growth is modest or negligible. In contrast, a young forest may have a relatively modest stock of carbon due to its small total biomass, but sequesters carbon at a fast rate due to the rapid growth of juvenile trees.

Present management practices for the ponderosa pine forest

A ponderosa pine forest can be managed under various silvicultural prescriptions that can ultimately result in an even-aged or uneven-aged stand. Typically, an even-aged stand results from the application of the following methods: two-cut or three-cut shelterwood, seed-tree, and/or clear-cutting.

An example of a two-stage shelterwood is illustrated below (Figure 4). Basal area is generally reduced below 60 ft^2 per acre (14 m^2 per hectare) in an initial entry using a marking regime that leaves a uniform canopy of the biggest and healthiest trees for a seed source (Figure 3). Abundant natural regeneration is usually produced within 5 to 10 years and all remaining overstory trees are removed once a new generation of trees is established.

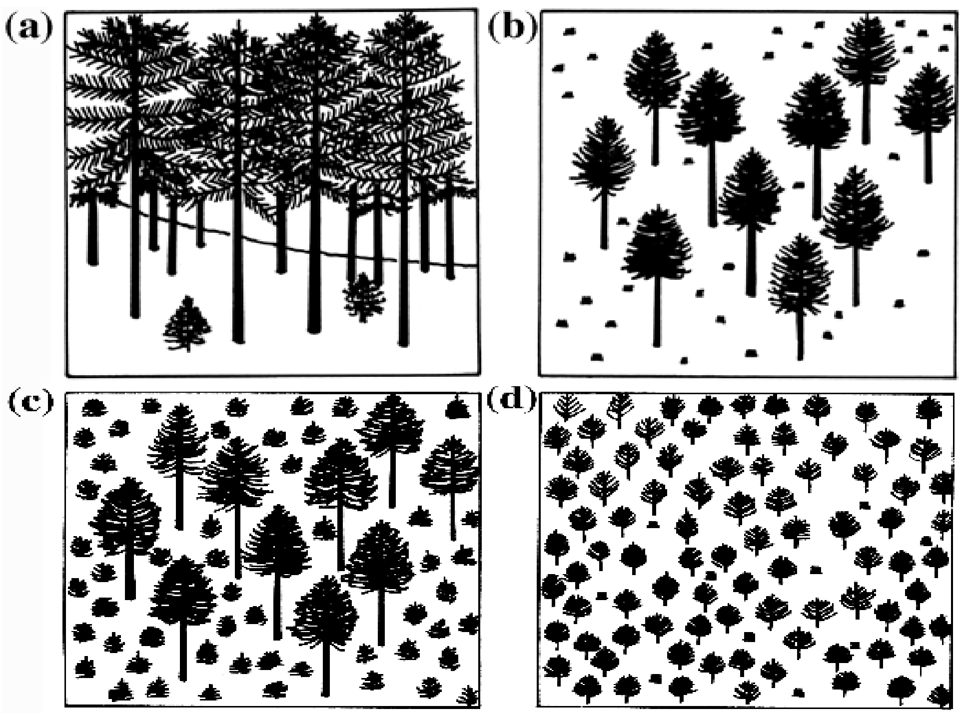

Figure 4. Diagram of a forest stand regenerating under a two-cut shelterwood management practice. (a) Prior to harvest, (b) immediately following a combined preparatory and seed cut, (c) regeneration becomes establishment after the first cut, and (d) established regeneration following the second cut, or removal cut.
(Source: http://www.ext.vt.edu/pubs/forestry/420-405/fig9.html)

Clear-cutting is generally recommended for ponderosa pine stands that are heavily infested with disease (particularly, dwarf mistletoe). Clearcutting can be applied in a patch where the cuts are small enough to allow seeds from surrounding stands to assist in reestablishing trees in forest openings (Figure 5).

Figure 5. An even-aged ponderosa pine stand in the Black Hills National Forest.

The goal of uneven-aged silviculture is to attain a forest comprised of trees of varying size and age classes (Figure 6). Uneven-aged stands provide for diversity within the stand structure and can be achieved through individual tree and group selection.

Figure 6. An uneven-aged ponderosa pine stand in the Black Hills National Forest.

Generation of carbon credit vs. economic profitability:

From the above discussion, one can ask the question "Which management technique will maximize the storage of carbon in addition to economic returns from the sale of forest products, while maintaining the health and sustainability of the forest?" To answer this question, we must consider carbon sequestration potentials of different management practices.

In the case of ponderosa pine, non-managed stands show greater carbon stocks than managed stands. The non-managed stand contains greater aboveground biomass in the form of living trees when compared to managed stands, although the size of these many of these trees are generally not marketable. Among managed stands there may be no significant differences in carbon stock. However, when considering the annual carbon sequestration rate, young even-aged stands sequester carbon at a higher rate than old non-managed and uneven-aged stands.

From an economic stand point, managed stands yield higher returns than do non-managed stands. Among managed stands, selective harvesting of a stand, or uneven-aged silviculture practices, yield more profit than even-aged stand management. In the case of even-aged stands, timber is harvested at the end of the rotation so there is an increased uncertainty or risk associated with profits due to natural disturbances like forest fire, pest infestations, and/or diseases.

The decision making process in forest management depends on the objective of the land owner. For ponderosa pine forest management, it is always better to manage the forest whether the land owner wants to maximize economic profit or to generate carbon credits. Under a managed system, forest mangers can switch over from an uneven-aged to even-aged forest if they can obtain an incentive for higher carbon sequestration when implementing even-aged management practices.

Present U.S. carbon markets

Participation in carbon trading programs is increasing due to added financial incentives and individual's attitudes towards ecological applications. In United States, forest carbon credits are provided by four U.S. “Registries” include 1) the Chicago Climate Exchange (CCX), 2) the Department of Energy (DOE) National Voluntary Reporting of Greenhouse Gases Program under section 1605(b) of the Energy Policy Act of 1992, 3) the California Climate Action Registry (CCAR), and 4) the Regional Greenhouse Gas Initiative (RGGI). At present, Chicago Climate Exchange (CCX) is the primary carbon trading system for forest lands. A comparison of the types of forestry projects involved in theses programs is presented in following table:

Forest Project Types within the U.S. Registries

DOE	CCAR	CCX	RGGI
Managed forests, forest restoration, afforestation, reforestation, agroforestry, short-rotation woody biomass plantations, low-impact harvesting, protecting existing forests from conversion to other uses, and urban forestry	Forest conservation, conservation-based management, and reforestation	Afforestation and reforestation, forest conservation, managed forests, and urban forests.	Afforestation

All these programs are still in developing phase. Market-based mechanisms to address the issue of forest carbon sequestration generate the opportunity to increase the return on investment and managed forests will play an important role in future.

Recommendations

Considering only per acre income and disregarding carbon storage levels, uneven-aged management scenarios will provide the most consistent return from ponderosa pine. Over an expected rotation however, timber volume harvested should not differ significantly from that realized from even-aged silvicultural management. When selecting the management system best for your property, consider the amount of wood harvested during each cutting and the interval between harvests as these will affect income distribution over time. In addition, the costs associated with multiple entries should be considered.

Tree size and age class diversity will be maximized with an uneven-aged system of management. Typically, this will reduce overall carbon storage potential due to slower carbon accumulation rates noted in larger trees when compared to early stage even-aged stands. Should carbon markets develop, with a resultant increase in the value of stored carbon, conversion to an even-aged management system will maximize sequestration potential but at the expense of accumulated ecosystem carbon. Income will be realized immediately from the sale of timber associated with this conversion, however additional income from harvest activity will not occur for another rotation. The income derived from the sale of sequestered carbon would potentially provide the landowner with an annualized income. The amount would obviously depend upon the value of carbon offsets. Currently, a carbon offset credit (1 metric ton of CO_2) sells in excess of $20.00 in Europe. This same credit sells for less than $5.00 in the North America, should a cap and trade system for CO_2 be initiated in North America, this value will increase. Although non-managed stands maximize stored carbon, no income is derived as a result of timber harvest. In addition, susceptibility to insect and disease infestation is greater as well as an increased fuel load making the property prone to wildfire.

The value of managed forest land expands beyond income derived from the sale of timber and potentially, the sale of stored carbon. Management results in healthier stands, with greater resistance to insect and disease attack. Additionally, due to reduced fuel loading, managed stands are at a reduced risk to wildland fire.

The average amount of carbon stored *per tree* in the Black Hills ponderosa pine forests ranges from approximately 1.0 lb C yr^{-1} (0.5 kg C yr^{-1}) in non-managed stands to 9.0 lb C yr^{-1} (4.0 kg C yr^{-1}) in the intensively managed stand. Of course, these estimates will vary, based on the age of the tree and the density of the stand. Relative comparisons of different forest management practices on the basis of economic profitability and carbon storage within forest stands are shown in the following table.

Comparison of ponderosa pine management practices on the basis of carbon storage and economic profitability (Chatterjee et al., 2007).

	Management Practices		
	Non-managed	**Even-aged**	**Uneven-aged**
Stand rotation (Years)	100-300	75	First selection cut at age 65
Expected timber yield (lifetime)	-0-	12 MBF ac^{-1} (30 MBF ha^{-1})	9.7 MBF ac^{-1} (24 MBF ha^{-1} or 8 MBF ha^{-1} at each entry; total 3 entries)
Expected annual payment	-0-	\$35 ac^{-1} yr^{-1} (\$87 ha^{-1} yr^{-1})	\$40 ac^{-1} yr^{-1} (\$98.50 ha^{-1} yr^{-1})
Potential ecosystem carbon storage*	110 ton C ac^{1} (250 Mg C ha^{-1})	72 ton C ac^{-1} (160 Mg C ha^{-1})	77 ton C ac^{-1} (170 Mg C ha^{-1})
Risk of fire and disease infestation	High	Low – Early Rotation High – Late Rotation	Medium

*Includes both above- and belowground carbon

References:

Chatterjee, A., G. F. Vance, S. Mooney, D. B. Tinker, and P. D. Stahl. 2007. Comparisons of carbon stocks and economic profitability of Wyoming coniferous forest management practices. Forest Ecology and Management (in review).

Chicago Climate Exchange. 2006. CCX® Forestry Carbon Emission Offsets. [Online]. Available at: http://www.chicagoclimatex.com/news/publications/pdf/CCX_Forest_Offsets.pdf (Posted 8th June, 2006; Verified 27th Feb., 2006).

Green, A.W. and R.C. Conner. 1989. Forests in Wyoming. Resource Bulletin INT-61. USDA, Forest Service. 91p.

Sheppard, W.D. and M.A. Battaglia. 2002. Ecology, Silviculture, and Management of Black Hills Ponderosa Pine. General Technical Report, RMRS-GTR-97. USDA, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.112 p.

Common unit conversions in forestry:

Wood Volume

1 MBF- Scribner, small (thousand board feet) = 0.1650 MCF (thousand cubic feet)
1 MBF- International ¼” = 0.1460 MCF
1 MBF-Scribner, long = 0.1450 MCF
1 MBF- Doyle= 0.2220 MCF
1 Cords= 0.0750 MCF

Area

1 hectare (ha) = 2.47 acre
1 ha = 10,000 square meter
1 acre= 0.405 ha
1 square meter = 10.76 square foot

Weight

1 Mega gram (Mg) = 1 Metric ton (Mt)
1 Mg = 10^3 kg = 10^6 gram = 2205 pound (lb)

Basic factors for converting merchantable wood yield to carbon yield for ponderosa pine

A. Specific gravity	B. Lbs per cubic ft. (A*62.4)	C. Merchantable wood to total biomass	D. Percent Carbon	E. Lbs carbon per cubic ft. (B*D)
0.38	23.71	2.254	0.512	12.14

For example,

4 MBF-Scribner, small per hectare timber is harvested from woodland

The amount of timber removed in cubic ft. = 4 * 0.1650*1000 = 660 cubic ft of timber,

Total biomass removed = 660*2.254 = 1488 cubic ft.

The carbon removed due to harvest = 1488*12.14

= **18,064 lb of carbon or 8.19 Mg of carbon**.